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Snowplow Simulator Training Evaluation:
Potential Fuel and Drivetrain Maintenance Cost Reductions

SIMULATOR-BASED DRIVER TRAINING

Driving simulators are used for training on cars, large trucks, and off-road equipment. As more realistic training programs have developed, simulators are now in use to train snowplow drivers in many states. The Arizona Department of Transportation (ADOT) introduced simulator-based training in late 2004, when maintenance crews in five rural districts were given a basic snowplow safety topics class by trainers from L-3 Communications on the TransSim VS III system.

ADOT's Arizona Transportation Research Center (ATRC) initiated project SPR 585 in mid-2004 with Arizona State University (ASU) to evaluate the initial training program.

ADOT purchased its first L-3 simulator in 2005 for the Globe District, initiating a far more extensive field training pilot program for 60-plus snowplow drivers. Local ADOT volunteer trainers, all experienced snowplow operators, took a "Train the Trainer" class from L-3 staff. Then, all Globe District crews took a four-hour basic driver awareness and space management course, with lectures and simulator snowplowing scenarios.

ADOT added two more simulators in the Holbrook and Flagstaff districts, to expand the program for 2006-07. These districts used the basic simulator-based driver awareness course to train all of their plow operators for the 2007-08 snow season. New drivers hired in Globe over the past year also took this driver awareness course. A fourth unit is to be installed in the Safford District in 2008.

The Simulator and FMDT Training

In early 2006, Globe trainers taught the basic L-3 Fuel Management Driving Techniques (FMDT) course to all drivers in the district. Those trained on safety awareness in the fall were now instructed on proper gear shifting techniques for better fuel economy with the FMDT training module. The primary manual transmission (M/T) focus was on smooth and efficient use of the gear shift, clutch, and accelerator, and information on automatic transmission (A/T) efficiency was also included in computer-based and lecture segments of the class.

The objective of this 2006-07 research project was to assess the benefits of simulator-based FMDT training in terms of fuel economy and routine repair costs for ADOT's heavy vehicle fleet. Its focus was on the Globe Maintenance District, with the first simulator deployed by ADOT. The FMDT course was given to all operators in the district in spring 2006, and to the newly-hired drivers in fall 2006 and spring-summer 2007.

The full benefits of simulator-based training will emerge only over time, but this study offers an initial assessment from Globe District records. The focus of this study was on:

1. Potential improvements to fuel economy, recorded in the simulator training session.
2. Driver performance in the real-world environment, in terms of fuel economy.
3. Changes in fuel economy and repair costs, related to proper driving/shifting skills.

Kirkpatrick's four-level evaluation model (*Evaluating Training Programs: The four levels*) was used to assess whether FMDT training improved fuel economy in the Globe District. At the basic *Reaction* level (Level 1), the results look positive; drivers and supervisors indicated that this training increased awareness and changed driving behavior related to fuel efficiency. At the *Learning* level (Level 2), results are similar to Project 585: some drivers improved, but some did worse in post-training runs.

At the *Performance* level (Level 3), field results are promising, as drivers of manual-shift trucks achieved, on average, a 4.5% improvement in fuel economy. But at the *Results* level (Level 4), the aggregate fuel economy figures by season for the ten trucks studied show no discernable difference between pre-training and post-training fuel economy on primary winter maintenance tasks.

Ideally, this study would show clear fuel economy improvements at the Learning, Performance, and Results levels of evaluation. The outcome did not fully meet expectations, but does offer insights that suggest some areas of promise in these areas.

Level 2: Learning

The more experienced drivers (10-plus years of truck driving) achieved the greatest improvement in estimated fuel economy, as indicated by the simulator's before and after training reports. This is encouraging; it suggests that the FMDT course can benefit even drivers who have many years of real-world experience — and had extensive driver training over those years. However, the training, as currently conducted, did not have the same impact on novices. Novice drivers, if given more practice time, may also be able to achieve similar results.

Level 3: Performance

The improvements achieved by drivers of manual shift trucks, averaging 4.5%, are substantial, the potential savings are significant when all M/T trucks are considered for the ADOT fleet. In 2006, ADOT consumed 1,079,068 gallons of diesel fuel, costing nearly $2.8 million. While these numbers are fleet-wide, and include many A/T vehicles, it is clear that even a modest improvement in fuel economy has the potential for significant dividends (especially as fuel costs continue to rise).

Level 4: Results

Due to several factors that affect post-training fuel economy, the results of the aggregate fuel study are largely inconclusive. Still, the study revealed some useful insights, described further below:

EVALUATION AREA 1:
Potential Fuel Savings

The research used data from Globe's 2006 FMDT training course in 2006, as the simulator estimates fuel consumption during a specific driving task. Each trainee shifted up through the gears from a standstill to 60 mph, then stopped, as a "pre-test." They then took the FMDT class, in which proper gear shifting was emphasized. After their training, drivers again "drove" the zero-to-sixty run, as a "post-test." Each trainee's mileage was displayed on the trainer's screen; simulated fuel economy was expected to improve in the post-test scenario.

While some drivers improved, others achieved worse fuel economy in post-test simulator runs. The unexpected fuel test results may simply be due to inadequate practice time in the simulator, or to inconsistent training among the districts, but this also may indicate FMDT software problems. There were issues with recording fuel-run mileage, and there were intermittent software problems with gear shifting on the simulator. The ADOT trainers formed a Simulator Working Group (SWG) in mid-2006 to address such issues.

EVALUATION AREA 2:
Globe to Show Low Fuel-Test Runs

The project attempted to measure fuel performance in a real-world driving environment. ADOT staff and the research team established a rural highway test route on US 60, between Globe and Show Low — a 168-mile, four-hour round trip. The route was through the Salt River Canyon, a winding road with many steep grades.

Two Mack snowplows were assigned to the study: one with an automatic transmission and one with a manual shift. Both trucks had GPS telemetry and engine computers to record elapsed time, distance, and fuel consumption. Each truck was "fully dressed" with rear spreader and snowplow blade, and loaded with sand equal to a load of de-icer.

Five newly-hired Globe drivers each made four round-trip fuel efficiency runs. Each made two trips prior to FMDT training (one in the M/T truck, and one with the A/T). These trips were repeated after taking the FMDT training course. Two experienced driver-trainers also made initial fuel runs, to establish a baseline miles-per-gallon mark.

The many challenges of real-world research made a rigorous before-after comparison impossible. The manual transmission truck consistently overheated, forcing the driver to reduce speed or pull off the road; drivers with the automatic transmission also sometimes slowed to wait for the manual truck.

Pre- and post-test runs were several months apart, in March-August and in September. Ambient temperatures varied, and were not normal for a fully dressed snowplow, an overheating factor. Due to these issues, and the small sample size, conclusions are somewhat speculative, but the evaluation has revealed some promising trends. On the M/T trucks, five trainees posted an average 4.5% improvement in fuel economy following the training, but, drivers on A/T trucks had a 6.1% *decrease* in fuel economy after FMDT training.

EVALUATION AREA 3:
Aggregate Fuel Economy & Repair Analysis

Fuel and repair records for 2005, 06, and 07 for the Globe District heavy truck fleet were reviewed by quarters, both before and after the FMDT training classes. The goal was to isolate the costs for winter (Q1) and for spring driving (Q2), since winter involves significant snow plowing, while spring activity focuses on road maintenance.

The FMDT training was given in spring 2006, so Globe's records were collected for all manual shift trucks from 2005 to 2007. Then, a subset of 10 trucks was selected for their extensive use in both winter and summer activities, to give an accurate picture of fleet fuel economy.

Globe's aggregate fleet fuel use data, based on work activity records by quarter, was analyzed for five significant "high-mile" task areas from the ADOT maintenance work database (PECOS), to compare pre- and post-training winters. However, no clear trends resulted in these primary task areas.

Specific driving techniques are one key factor in the frequency and extent of equipment repairs; age, quality, and exposure of the vehicles to damage are also factors. Globe's trucks are relatively new, and after several relatively mild winters, most units have not seen extensive severe duty yet. Also, some repairs to trucks may be postponed until late summer, as they are being prepared for the winter. Such costs would not appear in this study's review of first- and second-quarter repairs by season.

Globe fleet records showed no clear reduction in driveline repairs in the January-March winter quarters of 2005, 06 and 07. In fact, repair costs rose in 2007, after the FMDT training, due to one major transmission repair. Excluding that cost, the repairs in the first quarter of 2007 would show a substantial reduction from the two prior winters.

An additional cost of repairs is the time that trucks needing extensive repairs are out of service — a significant opportunity cost. During the winter months, when it is essential that all snowplows are in full readiness, major repairs could interfere with ADOT's commitment to keep roadways clear.

EVALUATION RESULTS

The premise of this study was that any post-training improvements to fuel economy would be evident in a review of the full fleet of trucks operating year-round in the Globe District. The results, however, suggest the fuel consumption picture is even more complex than anticipated. Potential fuel savings will vary, often greatly, with many external factors: transmission type, age and condition, activities, terrain and road conditions, and driver skills and techniques. The simulator can address only one fuel-related factor: driver skill and technique.

The literature underscores the importance of driving technique, but external factors also play a key role — more for highway agencies than for over-the-road trucking. Commercial drivers on interstate highways have a standard vehicle and a typical cargo, but DOT operators drive a mix of vehicles in a variety of activities on a diverse network of roads. Changes in fuel economy are therefore difficult to accurately capture. Still, focusing specifically on the Globe District's fleet of vehicles and range of operations, did help — at least to some degree — to isolate the role of the driver in fuel management and repairs.

ISSUES & RECOMMENDATIONS

ADOT's 585 study distinguished between tactical training (large concepts such as safety awareness) and operational training (more focused skills such as driving techniques). It concluded that simulators could be effective in training for both skill sets, but that measures of effectiveness for each of these types of training are necessarily quite different.

Tactical training is best measured qualitatively; operational training is measured quantitatively. The current study supports this, while at the same time

highlighting the challenges involved in such quantitative assessments. Future studies should therefore consider the following recommendations:

Data Reporting

It became clear over the course of the aggregate fleet study that the diverse ADOT systems used for recording fuel usage, job activity codes, etc., do not lend themselves to an integrated analysis. Separate systems (fuel logs from one source, driver/vehicle/task records from others) result in separate data sets, which are often difficult to integrate. A single, comprehensive, user-friendly reporting system would make it easier to monitor fleet performance. Indeed, if the system were user-friendly at the driver level, with feedback on a daily basis, operators would have a real sense of their fuel consumption. The research suggests that improvements to fuel efficiency are more likely to occur when immediate feedback is provided.

Improved Gear Shifting

Project 585 noted that drivers did not get enough practice time, and that "additional training is required to achieve over-learning," the rehearsal of actions past a minimal skill level so as to perform correctly in stressful situations. Driver training takes resources that otherwise focus on ADOT's core mission. Nevertheless, the investment in driving simulators has been substantial. To fully reap the benefits of this investment, new drivers must be allowed (perhaps *required*) the time necessary to develop real expertise in gear shifting technique – an issue for the Working Group.

Expansion of A/T Training

Some drivers in the fuel-run study would often override the programmed shifting of the automatic transmission (shifting to a lower gear), raising questions about "best practices" for driving trucks with automatic transmissions in the ADOT fleet. As these truck types become more common, the trainers should consider how proper transmission override techniques can be integrated into the FMDT program — another issue for the SWG.

Simulator Down Time

During the course of the research, the three district simulators frequently needed technical support. Display screens were inoperable at times, as was the simulator gear shifting feature, an obvious impediment to FMDT training. The effective use of multiple simulators poses challenges for ADOT in general, and for each host district in particular. Experience over time may support having a few mobile simulators (presumably in proper working order) to travel around the state, rather than many simulators in the districts across the state. There are tradeoffs with either approach; Flagstaff has recently deployed a simulator training trailer.

SUMMARY

While none of the results to date are clear evidence that the 2006 FMDT training in the Globe District has improved the overall fuel economy of its fleet of large trucks, this study *does* provide valuable insights to make improvements in the future; the greatest benefits will come from carefully integrating the simulator training into the larger ADOT training program.

Much of this integration has already taken place at the district level; future improvements will require greater accommodation at ADOT's management level. Among the key initiatives needed are:

- A state-level champion for simulator training.
- A completely new fuel usage reporting system.
- Formal recognition and incentives for the training Working Group.

The full report: *Snowplow Simulator Training Evaluation: Potential Fuel and Drivetrain Maintenance Cost Reductions*, by Dr. Mary Kihl with Donald Herring, Peter Wolf, Mike Finn and Peng Yang, of Arizona State University (Arizona Department of Transportation, report number FHWA-AZ-07-635, published December 2007) is available on the Internet. Educational and governmental agencies may order print copies from the Arizona Transportation Research Center, 206 S. 17 Ave., MD 075R, Phoenix, AZ 85007; Fax 602-712-3400. Businesses may order copies from ADOT's Engineering Records Section.